Moore, Terry (2014) Ubiquitous positioning: a pipe dream or reality? In: ION International Technical Meeting 2014, 27-29 January 2014, San Diego, California, USA.

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Ubiquitous Positioning: A Pipe Dream or Reality?

Professor Terry Moore
Nottingham Geospatial Institute
The University of Nottingham

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What is Ubiquitous Positioning?

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Multi-sensor, low-cost and robust positioning
- Based on single or multiple users
- Different types of platforms and sensors
- Autonomous or cooperative navigation

Seamless transition
- Different sensors
- Different platforms
- Different algorithms
- When transitioning between different environments

Plug-and-play concept

Continuous positioning across all environments
- Open areas, partially obstructed, indoor

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Ubiquitous Positioning
The Challenges

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New technology

More GNSS satellites

More GNSS signals

Communications

- *WiFi / RFID*
- *UWB, Sparse Band*
- *Digital broadcasting*

Pseudolites, Locatalites

Smaller, cheaper inertial sensors

Digital mapping (outdoor & indoor)

More processing power

Drives new applications

New applications

Seamless indoor-outdoor personal navigation

Intelligent Transport Systems

Rail signalling & control

Precision aircraft landing

Ships in harbours

Location-dependent billing

Virtual security fences

Tracking people/animals/assets

Social inclusion

Creates new challenges

With thanks to Dr Paul Groves, UCL

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Ubiquitous Positioning

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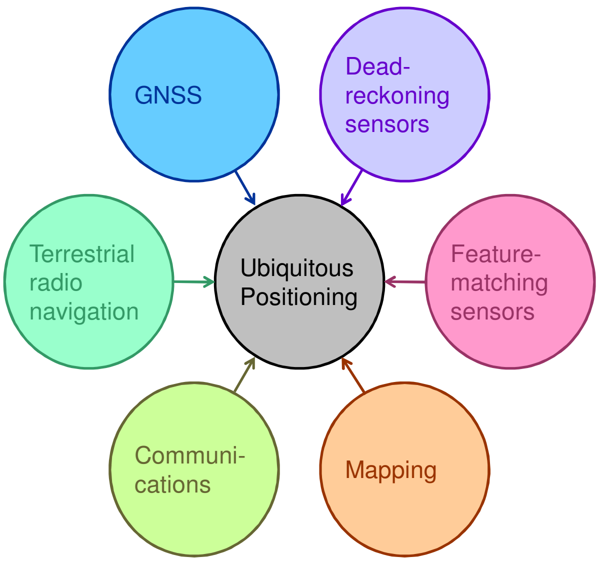

With thanks to Dr Paul Groves, UCL

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Application Scenarios

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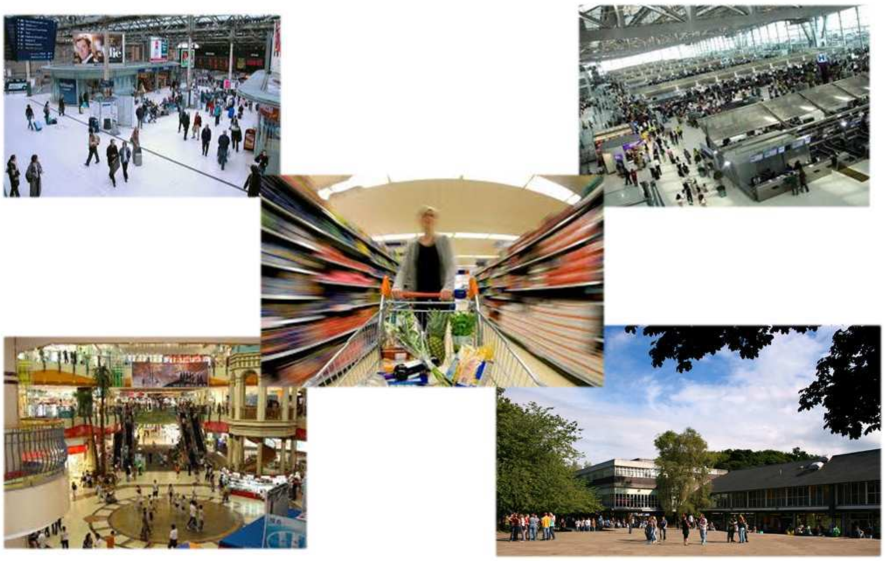

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Application Scenarios

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Transition Scenario

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Potential Platforms

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Space

Air
- Fixed wing
- Helicopter
- UAV/UAS




Land
- Indoor/outdoor
- Vehicle
- Autonomous
- Pedestrians





Water
- Ship
- Autonomous
- Man-portable



With thanks to Prof Dorota Grejner-Brzezinska, OSU

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Potential Technologies

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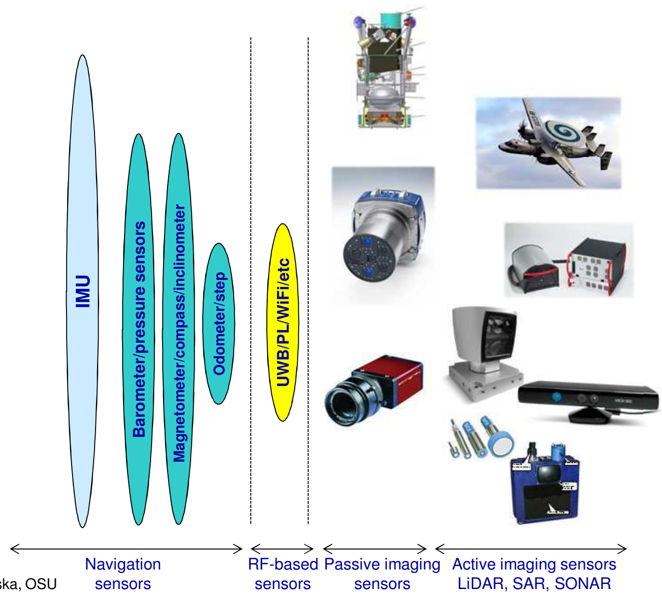
Space

Air
Fixed wing
Helicopter
UAV/UAS

Land
Indoor/outdoor
Vehicle
Autonomous
Pedestrians

Water
Ship
Autonomous
Man-portable



With thanks to Prof Dorota Grejner-Bzrezinska, OSU

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Infrastructure

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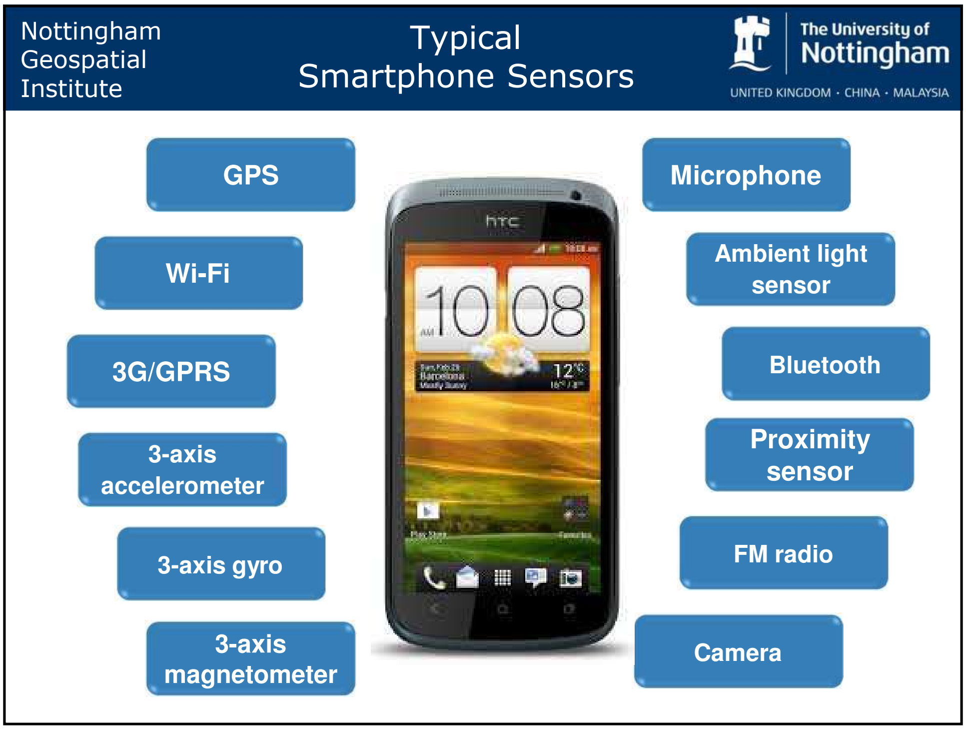
Dedicated Infrastructure
RFID or proximity devices
Ultra Wide Band
Static (building) or mobile (eg fire-tenders)
Airports, rail stations, shopping malls, universities

Ad hoc Infrastructure
WiFi access points
Signals of opportunity
Images, building information or plans

No Infrastructure
No existing infrastructure or destroyed
Only using sensors carried by the user
Autonomous or collaborative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Typical
Smartphone Sensors
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GPS
Wi-Fi
3G/GPRS
3-axis accelerometer
3-axis gyro
3-axis magnetometer
Microphone
Ambient light sensor
Bluetooth
Proximity sensor
FM radio
Camera


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Current Positioning Methods
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GPS
Wi-Fi
3G/GPRS
3-axis accelerometer
3-axis gyro
3-axis magnetometer
Microphone
Ambient light sensor
Bluetooth
Proximity sensor
FM radio
Camera

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Current Positioning Methods

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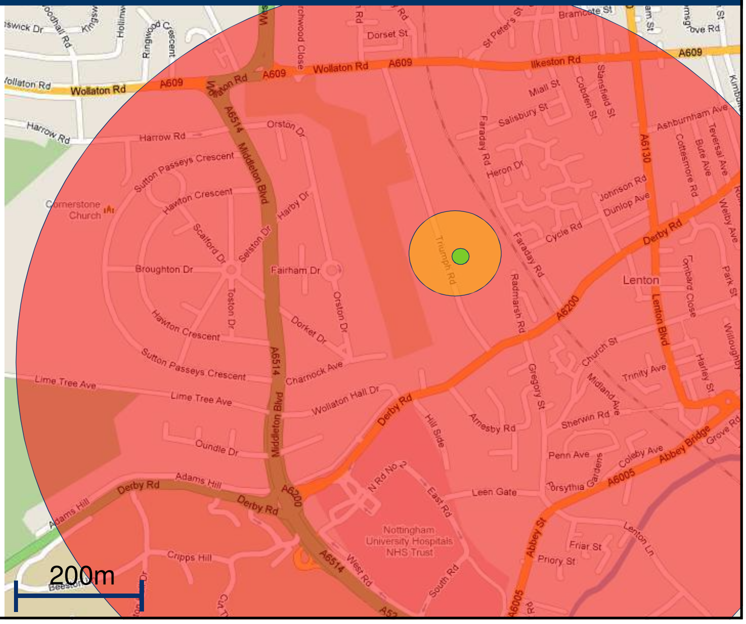
- Cell-ID
- Wi-Fi
- GPS



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Wi-Fi Fingerprinting

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- GPS
- Wi-Fi
- 3G/GPRS
- 3-axis accelerometer
- 3-axis gyro
- 3-axis magnetometer

- Microphone
- Ambient light sensor
- Bluetooth
- Proximity sensor
- FM radio
- Camera

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Wi-Fi Fingerprinting

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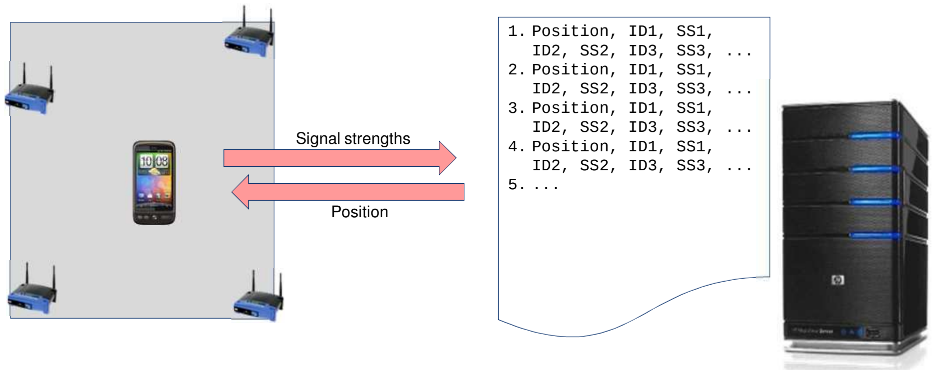
Measure signal strengths to all Access Points in view

Match measured signal strengths to database

Requires database of:

- Location
- signal strengths to all Access Points (APs) in view



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Signal Strength for one AP

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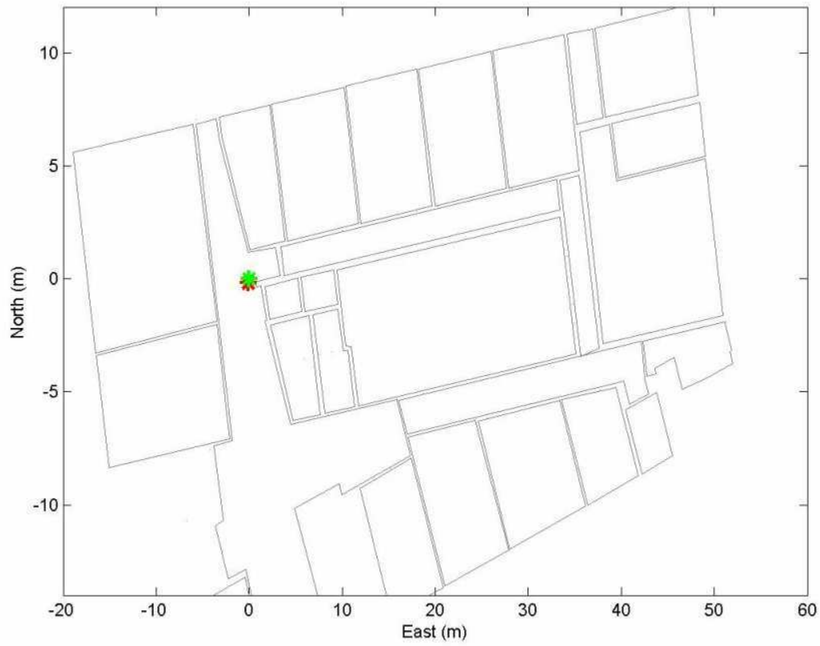
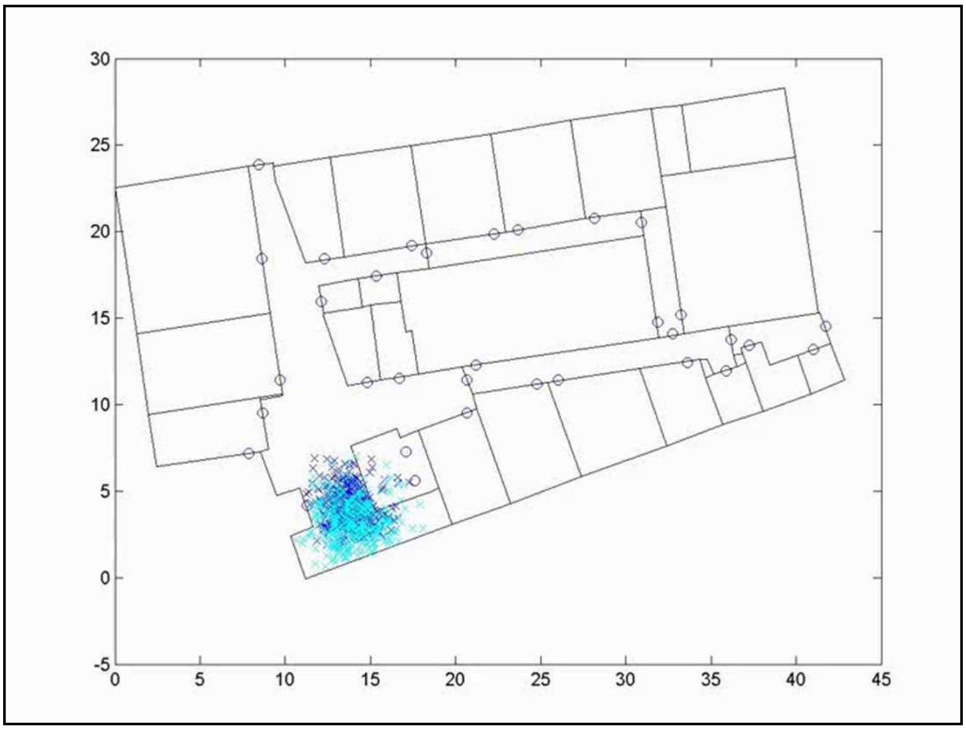
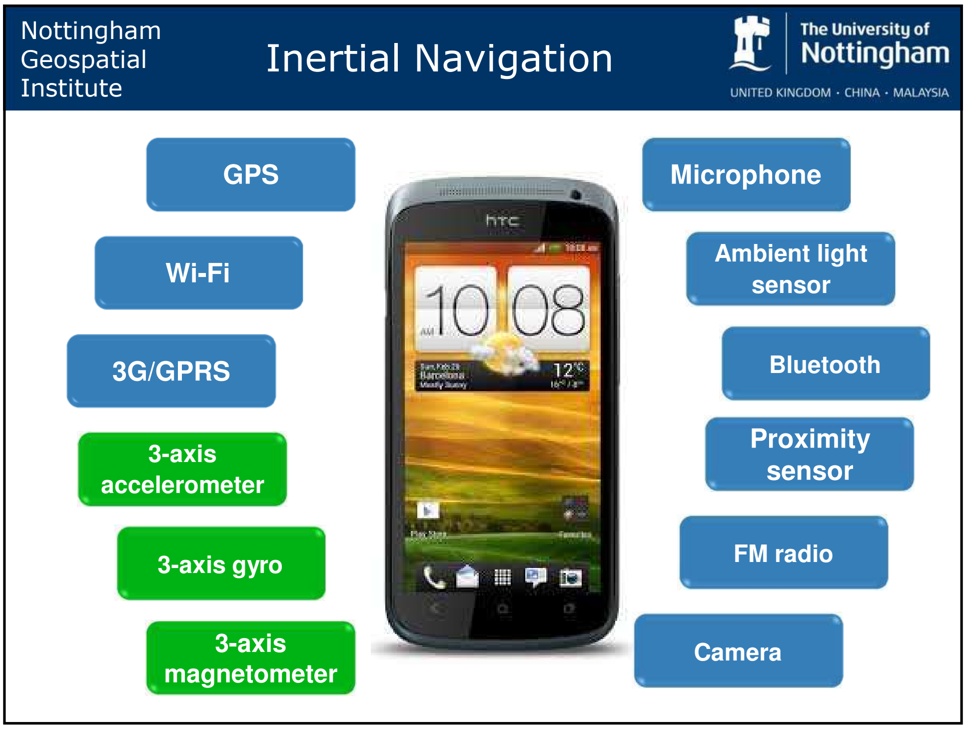


Wi-Fi Fingerprinting

- Works better indoors where walls/ceilings/furniture will attenuate signals the most
  - Accuracy comes from signal strength varying spatially
- Advanced algorithms
  - Particle filtering
- How do we build databases?
  - Skyhook use fleet of vehicles with GPS (tribe sourcing)
  - Google use crowd sourcing
- But what about inside where GPS isn't working?
  - Slow database generation using building plans
  - Scalability?
  - How do we keep the database up-to-date?



30
25
20
15
10
5
0
-5
0
5
10
15
20
25
30
35
40
45



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Inertial Navigation
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GPS
Wi-Fi
3G/GPRS
3-axis accelerometer
3-axis gyro
3-axis magnetometer
Microphone
Ambient light sensor
Bluetooth
Proximity sensor
FM radio
Camera

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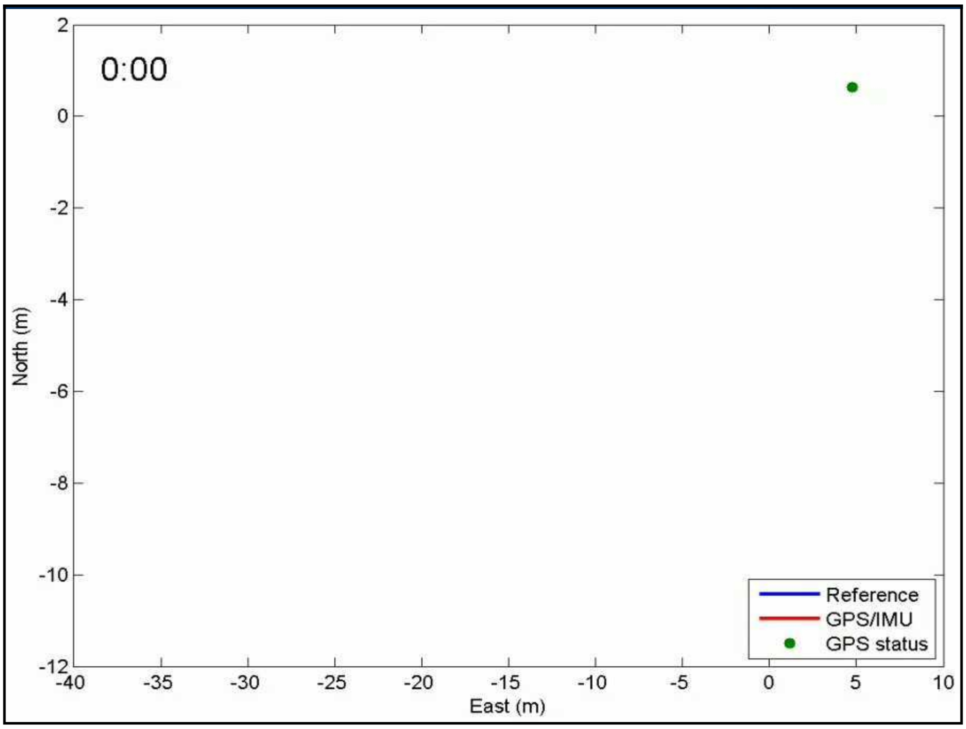
Inertial Navigation

- 3 gyros and 3 accelerometers
- Orientation from integrating gyro output
- Displacement from:
  - Rotate measurements to Earth frame (using gyros),
  - Removing gravity and …
  - Double integrating accelerations

- MEMS are getting better
  - Cheaper (higher volumes - Wii, smartphones)
  - Better manufacturing
  - Calibration

- Successful results usually from
  - Good sensors
  - Integration with GPS, magnetometers, zero velocity updates
  - Step detection algorithms



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Inertial Navigation

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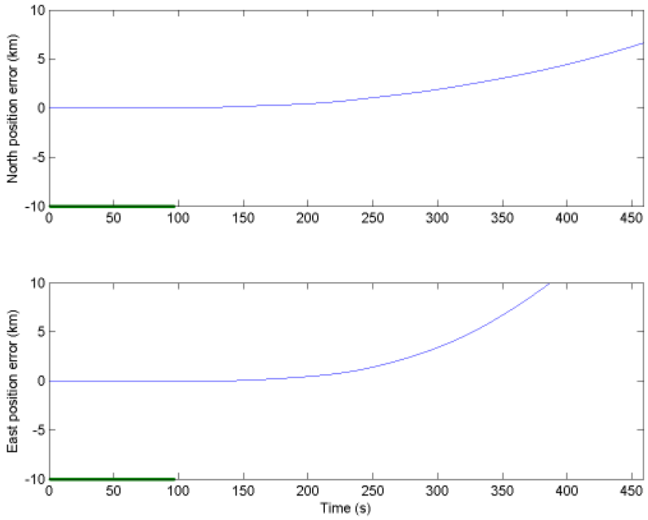

Time (s)	Horiz error (m)
60	231
120	891
180	2781
240	6297
300	11819
360	19287

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Computer Vision + Inertial Navigation

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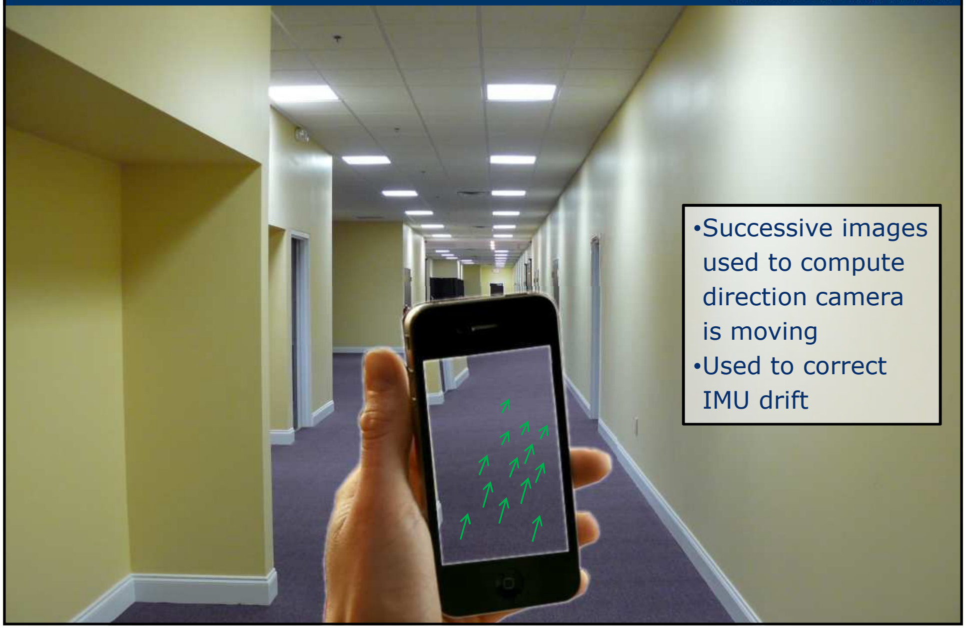
- GPS
- Wi-Fi
- 3G/GPRS
- 3-axis accelerometer
- 3-axis gyro
- 3-axis magnetometer

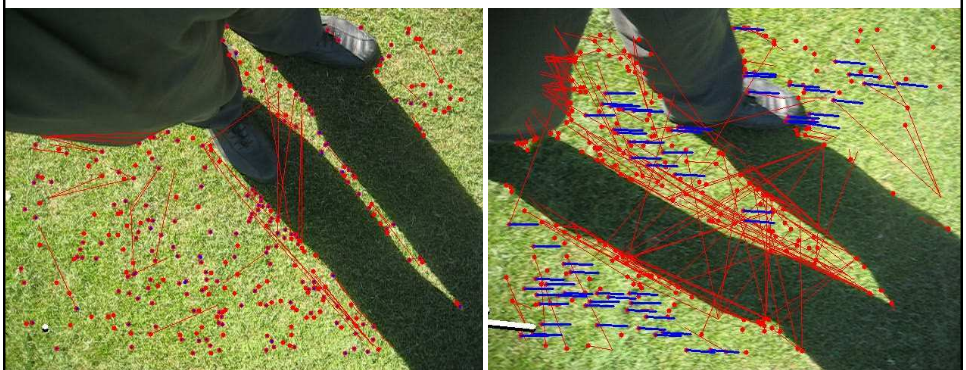
- Microphone
- Ambient light sensor
- Bluetooth
- Proximity sensor
- FM radio
- Camera

Vision Aided Inertial Navigation



Vision Aided Inertial Navigation

Examples…



Blue (inlier correspondences)
Red (outlier correspondences)

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Integration Strategy

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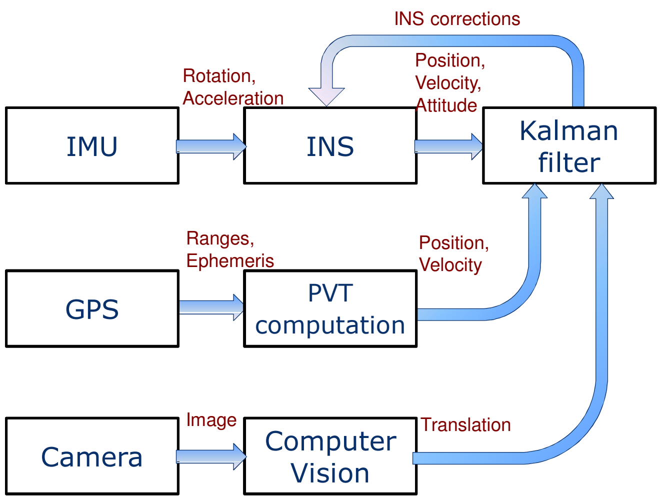

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Vision Aided Experiment

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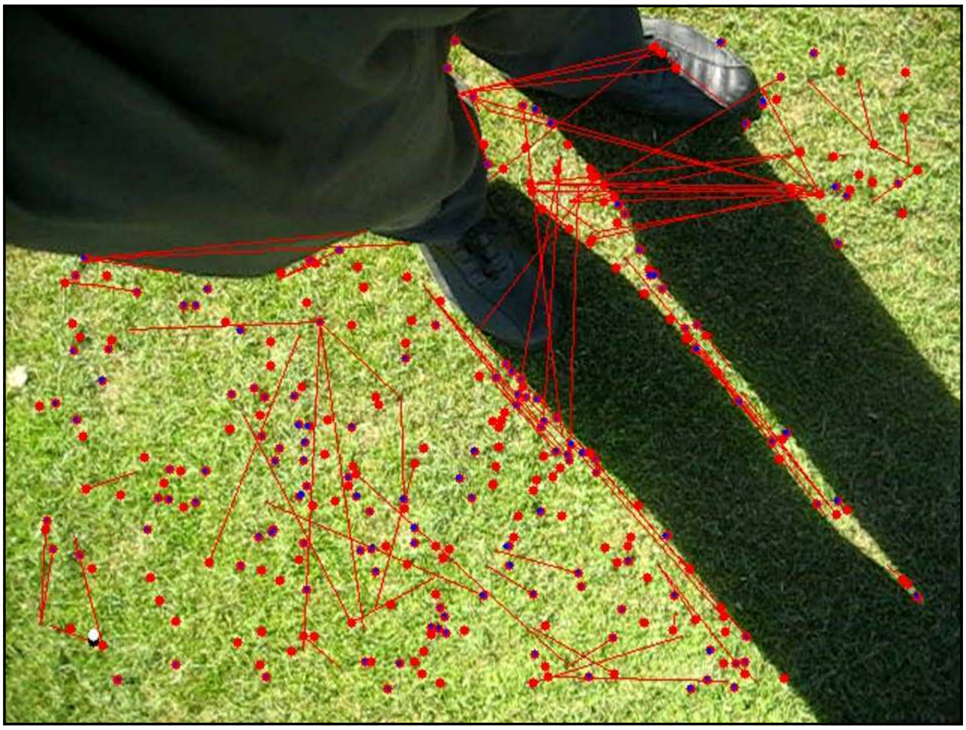

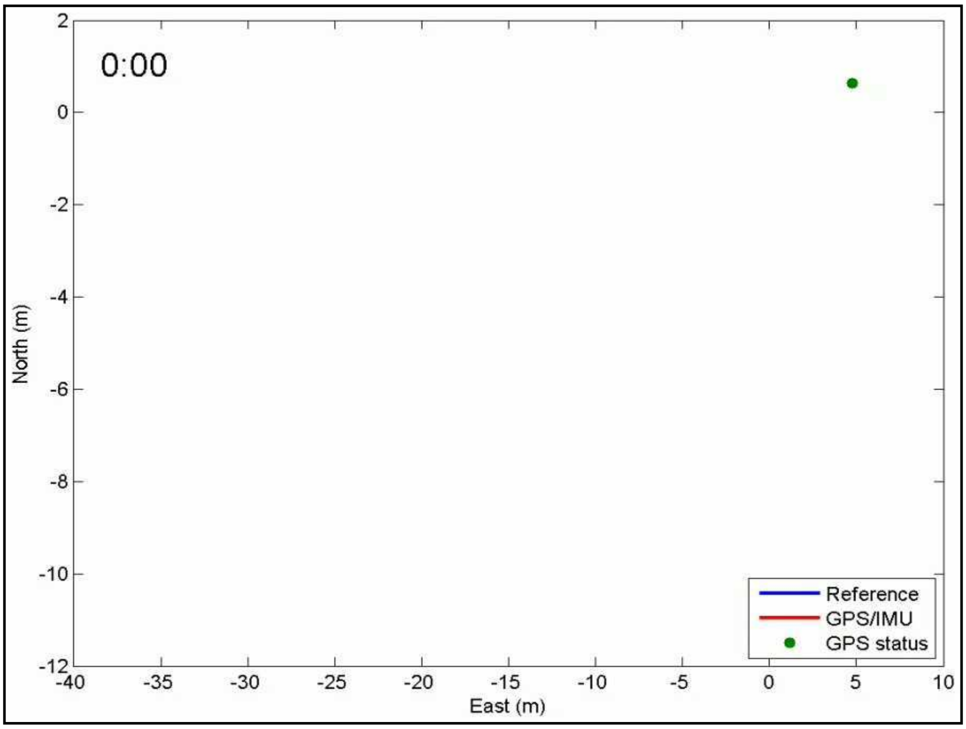
0:00
North (m)
East (m)
2
0
-2
-4
-6
-8
-10
-12
-40
-35
-30
-25
-20
-15
-10
-5
0
5
10
Reference
GPS/IMU
GPS status

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Position Accuracy

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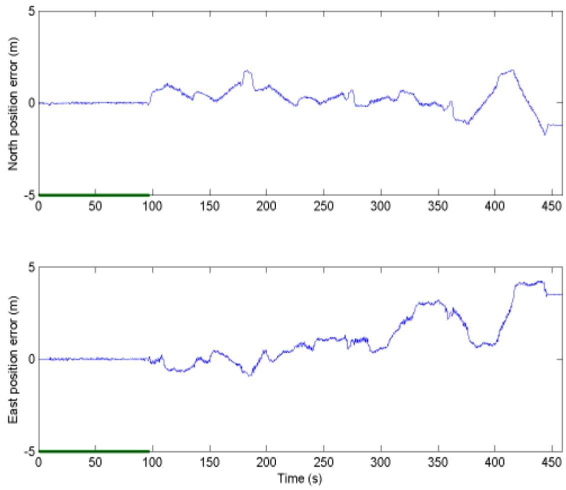

Time (s)	Horiz error (m)
60	0.4
120	0.4
180	0.9
240	3.0
300	0.9
360	3.7

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GPS+IMU+Vision

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Advantages

- Good position accuracy
- Makes use of sensors already on smartphones
- Handheld
- Works with or without GPS

Disadvantages

- Needs to be initialised e.g. with GPS
- Problems in low light conditions
- Computationally expensive

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Foot Mounted INS

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High accuracy indoor positioning system

- Foot mounted Inertial Measurement Unit (IMU)
- Zero velocity update, every step
- IMU <$2000
- Requires initialisation on known point
- Novel heading algorithm used to correct heading errors
- Shown to consistently maintain <5m accuracy over 40 minutes

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Foot Mounted INS

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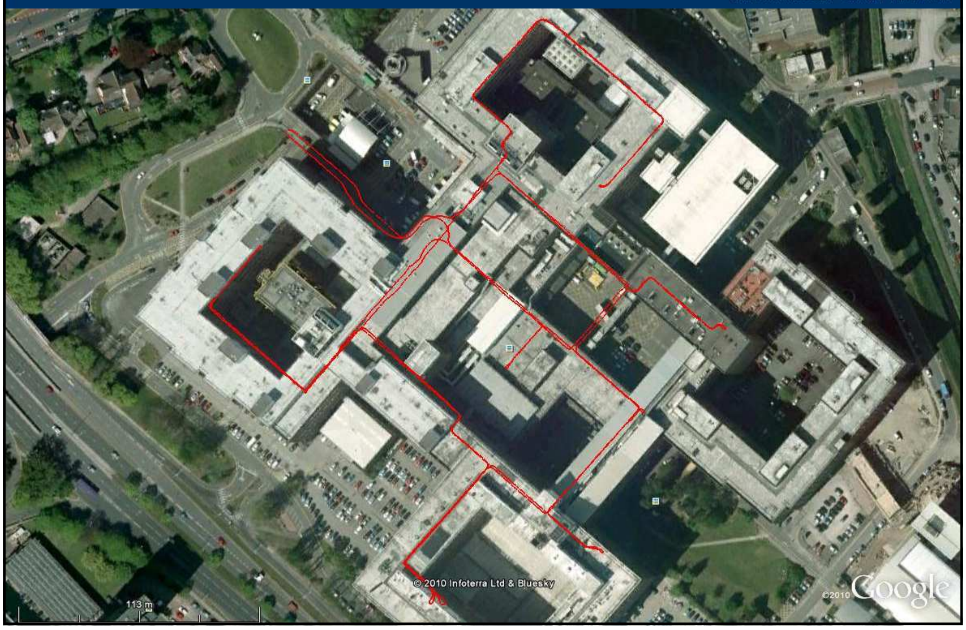

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Ubiquitous Positioning
FIG & IAG Working Groups

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- Joint between FIG WG 5.5 & IAG WG 4.1.1
- Performance characterization of positioning sensors and technologies for ubiquitous positioning systems
- Theoretical and practical evaluation of current algorithms for measurement integration
- Development of new measurement integration algorithms
- Joint Field Experiments
  - The Ohio State University, September 2010
  - The University of Nottingham, May 2012

www.ubpos.net

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Ubiquitous Positioning
FIG & IAG Field Trials

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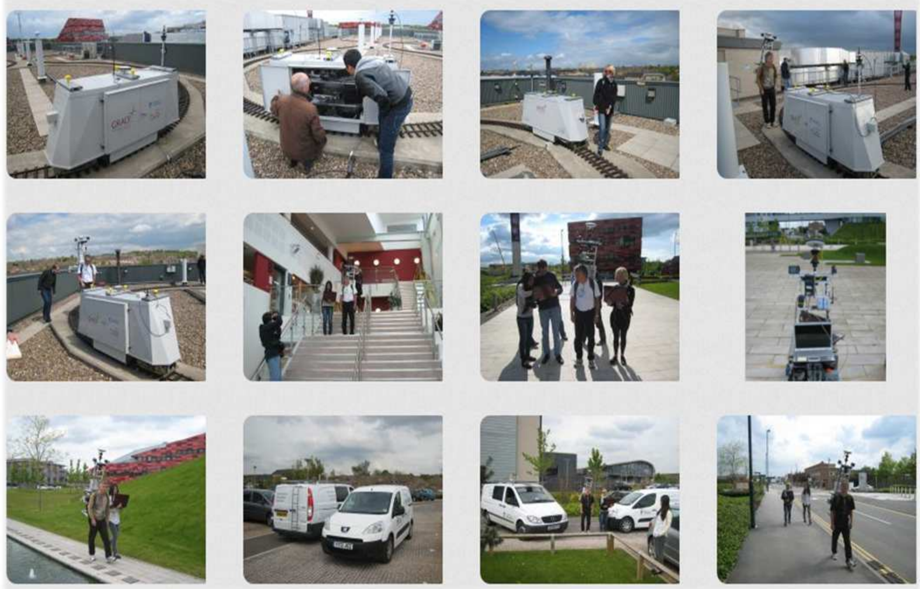

Navigation Philosophy

Positioning Sensor Fusion

- Clear synergy between GNSS and INS
- Focus has been on 'fixing' GNSS to provide continuity
- Tailored blend of sensors for particular scenarios

A Changed Navigation Philosophy

- Consider INS as the primary navigational sensor
- Focus has to be on bounding the growth of INS error
- Flexible and adaptive blend with other sensors
- *'Plug and Play'*

Research Challenges

- Flexible software architecture
- Adaptive filtering / fusion of the data
- Stochastic transition between different hybridisations

Contact Details

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